Attorney's Docket No. 1015290-000546 AF IFW

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of	
David J. Cooperberg et al.	Group Art Unit: 1763
Application No.: 10/024,208	Examiner: Luz L. Alejandro Mulero
Filed: December 21, 2001	Appeal No.: Unassigned
For: TUNABLE MULTI-ZONE GAS INJECTION SYSTEM	

SUBSTITUTE SECOND APPEAL BRIEF

Mail Stop APPEAL BRIEF - PATENTS
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

This is an Amended Second Appeal Brief in response to the Notification of Non-Compliant Appeal Brief dated May 15, 2007. A Second Appeal Brief was filed on January 8, 2007.

This appeal is from the decision of the Primary Examiner dated September 7, 2006, finally rejecting claims 1-11, 13-15 and 39-61, which are reproduced as the Claims Appendix of this brief.

No additional fees are required for this submission.

The Commissioner is hereby authorized to charge any appropriate fees under 37 C.F.R. §§1.16, 1.17, and 1.21 that may be required by this paper, and to credit any overpayment, to Deposit Account No. 02-4800.

I. Real Party in Interest

The present application is assigned to Lam Research Corporation ("Lam").

II. Related Appeals and Interferences

The Appellants' legal representative, or assignee, does not know of any other appeal or interference, which will affect, or be directly affected by, or have bearing on, the Board's decision in the pending appeal.

III. Status of Claims

Claims 1-11, 13-15 and 39-61 are pending in this application, were finally rejected and are being appealed. Claims 12 and 16-38 have been cancelled.

IV. Status of Amendments

No Amendments were filed subsequent to the final Official Action dated September 7, 2006.

V. Summary of Claimed Subject Matter

Claims 1-11, 13-15 and 39-61 are directed to a plasma processing system. Claims 1, 7, 9, 10, 41 and 42 are independent claims. In accordance with 37 C.F.R. § 41.37(2)(c)(v), a concise explanation of the subject matter defined in each of the independent claims follows, the explanation including references to exemplary locations in the specification by page and line number, and to the drawings.

A. Claim 1

Claim 1 recites a plasma processing system comprising a plasma processing chamber (**10** - e.g., Figure 1 and page 10, line 21); a vacuum pump (page 10, line 28) connected to the processing chamber; a substrate support (**12** - e.g., Figure 1 and page 11, lines 8-9) on which a substrate (**13** - e.g., Figures 1 and 3a-3c and page 10, line 22) is processed within the processing chamber; a dielectric member (**20** - e.g., Figures 1 and 2a-2c and page 11, lines 1-2) having an interior surface (Figure 1) facing the substrate support, wherein the dielectric member forms a wall of the processing chamber; a gas injector (**22** - Figures 1, 2a-2c and 3a-3c and page 11, line 4) extending through the dielectric member, the gas injector comprising a body (Figures 1, 2a-2c and 3a-3c) including an axial end surface (Figures 1 and 2a-2c) exposed within the processing chamber, a side surface (Figures 1 and 2a-2c) extending axially from the axial end surface, and a plurality of gas outlets (**24, 26** - e.g., Figures 2a-2c and page 12, lines 2-6) including at least one on-axis outlet (**24** - e.g., page 12, line 3) in the axial end surface and a plurality of spaced-apart off-axis outlets (**26** - e.g., page 12, lines 4-5, and page 14, lines 6-8) in the side surface, the off-axis outlets inject process gas at an acute angle (e.g., page 14, lines 11-13) relative to a plane parallel to an exposed surface of the substrate (see also page 12, lines 4-6); a common gas supply (**23, 32** - Figure 1 and page 11, line 6) in fluid communication with a first gas line (Figures 2a-2c) and a second gas line (Figures 2a-2c), the first gas line being in fluid communication with the on-axis outlet but not with the off-axis outlets (Figures 2a-2c) and the second gas line being in fluid communication with the off-axis outlets but not with the on-axis outlet (Figures 2a-2c); flow controllers (**36a, 36b** - Figures 2a-2c and page 12, lines 9-11) operable to

supply process gas from the common gas supply at flow rates that are independently varied between the on-axis outlet and the off-axis outlets into the processing chamber (page 12, lines 13-14); and an RF energy source (**18, 19** - Figure 1 and page 10, lines 24-28) which inductively couples RF energy through the dielectric member and into the chamber to energize the process gas into a plasma state to process the substrate.

B. Claim 7

Claim 7 recites a plasma processing system comprising a plasma processing chamber (**10** - e.g., Figure 1 and page 10, line 21); a vacuum pump (page 10, line 28) connected to the processing chamber; a substrate support (**12** - e.g., Figure 1 and page 11, lines 8-9) on which a substrate (**13** - e.g., Figures 1 and 3a-3c and page 10, line 22) is processed within the processing chamber; a dielectric member (**20** - e.g., Figures 1 and 2a-2c and page 11, lines 1-2) having an interior surface (Figure 1) facing the substrate support, wherein the dielectric member forms a wall of the processing chamber; a gas injector (**22** - Figures 1, 2a-2c and 3a-3c and page 11, line 4) extending through the dielectric member such that a distal end of the gas injector is exposed within the processing chamber, the gas injector including a planar axial end face (Figures 1 and 2a-2c) having an on-axis outlet (**24** - e.g., page 12, line 3) therein and a conical side surface (Figures 2a-2c) having off-axis outlets (**26** - e.g., page 12, lines 4-5, and page 14, lines 6-8) therein, the on-axis outlet receiving process gas from a central passage (**25** – e.g., Figures 2a-2c and page 12, line 20) in the injector and the off-axis outlets receiving process gas from an annular passage (Figures 2a-2c) surrounding the central passage, the gas injector supplying process

gas at flow rates that are independently varied between the on-axis outlet and the off-axis outlets into the processing chamber (e.g., page 12, lines 13-14); a common gas supply (**23, 32** - Figures 1 and 2a-2c, page 11, line 6, and page 12, lines 6-9) in fluid communication with a first gas line (Figures 2a-2c) and a second gas line (Figures 2a-2c), the first gas line being in fluid communication with the on-axis outlet but not with the off-axis outlets and the second gas line being in fluid communication with the off-axis outlets but not with the on-axis outlet (Figures 2a-2c); and an RF energy source (**18, 19** - Figure 1 and page 10, lines 24-28) which inductively couples RF energy through the dielectric member and into the chamber to energize the process gas into a plasma state to process the substrate.

C. Claim 9

Claim 9 recites a plasma processing system comprising a plasma processing chamber (**10** - e.g., Figure 1 and page 10, line 21); a vacuum pump (page 10, line 28) connected to the processing chamber; a substrate support (**12** - e.g., Figure 1 and page 11, lines 8-9) on which a substrate (**13** - e.g., Figures 1 and 3a-3c and page 10, line 22) is processed within the processing chamber; a dielectric member (**20** - e.g., Figures 1 and 2a-2c and page 11, lines 1-2) having an interior surface facing the substrate support, wherein the dielectric member forms a wall of the processing chamber; a gas injector (**22** - Figures 1, 2a-2c and 3a-3c and page 11, line 4) extending through the dielectric member such that a distal end of the gas injector is exposed within the processing chamber, the gas injector including at least one on-axis outlet (**24** - e.g., page 12, line 3) which injects process gas in an axial direction perpendicular to a plane parallel to an exposed surface of the substrate

(page 12, lines 3-4) and off-axis gas outlets (**26** - e.g., page 12, lines 4-5, and page 14, lines 6-8) which inject process gas at an acute angle (e.g., page 14, lines 11-13) relative to the plane parallel to the exposed surface of the substrate, the off-axis outlets being circumferentially spaced apart from each other (e.g., page 14, lines 7-8), the gas injector supplying process gas at flow rates that are independently varied between the on-axis outlet and the off-axis outlets into the processing chamber (page 12, lines 13-14); a common gas supply (**23, 32** - Figure 1 and page 11, line 6) in fluid communication with a first gas line and a second gas line (Figures 2a-2c), the first gas line being in fluid communication with the on-axis outlet but not with the off-axis outlets and the second gas line being in fluid communication with the off-axis outlets but not with the on-axis outlet; and an RF energy source (**18, 19** - Figure 1 and page 10, lines 24-28) which inductively couples RF energy through the dielectric member and into the chamber to energize the process gas into a plasma state to process the substrate.

D. Claim 10

Claim 10 recites a plasma processing system comprising a plasma processing chamber (**10** - e.g., Figure 1 and page 10, line 21); a vacuum pump (page 10, line 28) connected to the processing chamber; a substrate support (**12** - e.g., Figure 1 and page 11, lines 8-9) on which a substrate (**13** - e.g., Figures 1 and 3a-3c and page 10, line 22) is processed within the processing chamber; a dielectric member (**20** - e.g., Figures 1 and 2a-2c and page 11, lines 1-2) having an interior surface facing the substrate support, wherein the dielectric member forms a wall of the processing chamber; a gas injector (**22** - Figures 1, 2a-2c and 3a-3c and page

11, line 4) removably mounted in an opening in the dielectric member (Figures 2a-2c and 3a-3c) and extending through the dielectric member such that a single distal end of the gas injector is exposed within the processing chamber (Figures 2a-2c), a vacuum seal (page 14, lines 14-23) being provided between the gas injector and the dielectric member, the gas injector including a plurality of gas outlets in the single distal end which are each located below the interior surface of the dielectric member (Figures 2a-2c), the gas outlets including at least one on-axis outlet (**24** - e.g., page 12, line 3) and a plurality of off-axis outlets (**26** - e.g., page 12, lines 4-5, and page 14, lines 6-8), the gas outlets supplying process gas at flow rates that are independently varied between the on-axis outlets and the off-axis outlets into the processing chamber (page 12, lines 13-14); a common gas supply (**23, 32** - Figures 1 and 2a-2c and page 11, line 6, and page 12, lines 6-9) in fluid communication with a first gas line and a second gas line (Figures 2a-2c), the first gas line being in fluid communication with the on-axis outlet but not with the off-axis outlets and the second gas line being in fluid communication with the off-axis outlets but not with the on-axis outlet (Figures 2a-2c); and an RF energy source (**18, 19** - Figure 1 and page 10, lines 24-28) which inductively couples RF energy through the dielectric member and into the chamber to energize the process gas into a plasma state to process the substrate.

E. Claim 41

Claim 41 recites a plasma processing system comprising a plasma processing chamber (**10** - e.g., Figure 1 and page 10, line 21); a vacuum pump (page 10, line 28) connected to the processing chamber; a substrate support (**12** -

e.g., Figure 1 and page 11, lines 8-9) on which a substrate (**13** - e.g., Figures 1 and 3a-3c and page 10, line 22) is supported within the processing chamber; a dielectric member (**20** - Figures 1 and 2a-2c and page 11, lines 1-2) having an interior surface facing the substrate support, the dielectric member forming a wall of the processing chamber; a gas injector body (**22** - Figures 1, 2a-2c and 3a-3c and page 11, line 4) extending through the dielectric member such that a distal end of the gas injector body is exposed within the processing chamber (Figures 2a-2c and 3a-3c), the gas injector body including a plurality of gas outlets (**24, 26** - e.g., Figures 2a-2c and page 12, lines 2-6) which are disposed within the processing chamber below the interior surface of the dielectric member, the gas outlets including at least one on-axis outlet (**24** - e.g., page 12, line 3) and a plurality of off-axis outlets (**26** - e.g., page 12, lines 4-5, and page 14, lines 6-8) which inject process gas at an acute angle relative to a plane parallel to an exposed surface of the substrate; a common gas supply (**23, 32** - Figures 1 and 2a-2c and page 11, line 6, and page 12, lines 6-9) in fluid communication with a first gas line and a second gas line, the first gas line being in fluid communication with the at least one on-axis outlet but not with off-axis outlets and the second gas line being in fluid communication with the off-axis outlets but not with the on-axis outlet (Figures 2a-2c); flow controllers (**36a, 36b** - Figures 2a-2c and page 12, lines 9-11) providing independently adjustable flow rates of process gas between the on-axis and the off-axis outlets into the processing chamber; and an RF energy source (**18, 19** - Figure 1 and page 10, lines 24-28) which inductively couples RF energy through the dielectric member and into the chamber to energize the process gas into a plasma state to process the substrate.

F. Claim 42

Claim 42 recites a plasma processing system comprising a plasma processing chamber (**10** - e.g., Figure 1 and page 10, line 21); a vacuum pump (page 10, line 28) connected to the processing chamber; a substrate support (**12** - e.g., Figure 1 and page 11, lines 8-9) on which a substrate (**13** - e.g., Figures 1 and 3a-3c and page 10, line 22) is processed within the processing chamber; a dielectric member (**20** - e.g., Figures 1 and 2a-2c and page 11, lines 1-2) having an interior surface facing the substrate support, the dielectric member forming a wall of the processing chamber; a gas injector (**22** - Figures 1, 2a-2c and 3a-3c and page 11, line 4) comprising an injector body including at least first and second gas inlets, at least first and second gas passages, an axial end surface, a side surface extending from the axial end surface toward the interior surface of the dielectric member, and at least a first gas outlet in the axial end surface and a plurality of second gas outlets in the side surface at locations between the axial end surface and the interior surface of the dielectric member (**24, 26** - e.g., Figures 2a-2c and page 12, lines 2-6), the second gas outlets (**26** - e.g., page 12, lines 4-5, and page 14, lines 6-8) inject process gas at an acute angle relative to a plane parallel to an exposed surface of the substrate, the first gas passage being in fluid communication with the first inlet and first outlet, and the second gas passage being in fluid communication with the second inlet and second outlet, the first and second gas passages not being in fluid communication with each other; a common gas supply in fluid communication with the first gas passage and the second gas passage (Figures 2a-2c); flow controllers (**36a, 36b** - Figures 2a-2c and page 12, lines 9-11) providing independently adjustable flow rates of gas through the first and second outlets; and an RF energy

source (**18, 19** - Figure 1 and page 10, lines 24-28) which inductively couples RF energy through the dielectric member and into the chamber to energize the process gas into a plasma state to process the substrate.

VI. Grounds of Rejection to be Reviewed on Appeal

1) The rejection of Claims 1-11, 13, 14 and 39-61 under 35 U.S.C. § 103(a) as allegedly being obvious over WO 00/41212 to Ni et al. ("Ni") in view of WO 99/57747 to Chang ("Chang") or U.S. Patent No. 6,450,117 to Murugesh et al. ("Murugesh") and U.S. Patent No. 5,958,140 to Arami et al. ("Arami"), or U.S. Patent No. 5,532,190 to Goodyear et al. ("Goodyear"), or U.S. Patent 6,090,210 to Ballance et al. ("Ballance").

2) The rejection of Claim 15 under 35 U.S.C. § 103(a) as allegedly being obvious over Ni in view of Chang or Murugesh and Arami, Goodyear, or Ballance, and further in view of U.S. Patent No. 6,287,643 to Powell et al. ("Powell").

VII. Argument

A. Legal Standards for Obviousness

As set forth in 35 U.S.C. § 103(a):

> A patent may not be obtained though the invention is not identically disclosed or described ... if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. (Emphasis added.)

The Office has the initial burden of establishing a factual basis to support the legal conclusion of obviousness. *See In re Oetiker*, 977 F.2d 1443, 1445, 24

USPQ2d 1443, 1444 (Fed. Cir. 1992); *In re Piasecki*, 745 F.2d 1468, 1472, 223 USPQ 785, 788 (Fed. Cir. 1984). The Office must make the factual determinations set forth in *Graham v. John Deere Co.*, 383 U.S. 1, 17, 148 USPQ 459, 467 (1966). These factual determinations are: 1) the scope and content of the prior art; 2) the differences between the prior art and the claims at issue; 3) the level of ordinary skill in the art; and 4) any relevant secondary considerations, including commercial success, long felt but unsolved needs, and failure of others.

Regarding the scope and content of the prior art, where it is alleged that claim limitations are found in a combination of prior art references, it must be determined "[w]hat the prior art teaches, <u>whether it teaches away from the claimed invention</u>, and whether it motivates a combination of teachings from different references" (emphasis added). *Dystar Textilfarben GMBH & Co. Deutschland KG v. C.H. Patrick Co.*, No. 06-1088 (Fed. Cir. October 3, 2006). *See also In re Fulton*, 391 F.3d 1195, 1199-1200, 73 USPQ 1141, 1144 (Fed. Cir. 2004).

For rejections under 35 U.S.C. § 103 that are based upon a combination of prior art elements, the Supreme Court stated in *KSR Int'l v. Teleflex Inc.*, 127 S.Ct. 1727, 1741, 82 USPQ2d 1385, 1396 (2007), that "[a]s is clear from cases such as *Adams*, a patent composed of several elements is not proved obvious merely by demonstrating that each of its elements was, independently, known in the prior art." To the contrary, the Office must also provide articulated reasoning with rational underpinnings to support the alleged obviousness of the claimed subject matter. As stated in *In re Kahn*, 441 F.3d 977, 988, 78 USPQ2d 1329, 1336 (Fed. Cir.), "rejections on obviousness grounds cannot be sustained by mere conclusory statements; instead, there must be some articulated reasoning with some rational

underpinning to support the legal conclusion of obviousness." *See also In re Fine*, 837 F.2d 1071, 1073, 5 USPQ2d 1596, 1598 (Fed. Cir. 1988).

Only if the Office carries its initial burden does the burden of coming forward with evidence or argument shift to the Appellant. *See Oetiker*, 977 F.2d at 1445, 24 USPQ2d at 1444; *Piasecki*, 745 F.2d at 1472, 223 USPQ at 788. The obviousness determination is then made based on the evidence as a whole and the relative persuasiveness of the arguments. *See Oetiker*, 977 F.2d at 1445, 24 USPQ2d at 1444; *Piasecki*, 745 F.2d at 1472, 223 USPQ at 788.

An applicant can rebut a *prima facie* case of obviousness with evidence of secondary indicia of nonobviousness. The determination of relevant secondary considerations is one of the factual determinations mandated by *Graham v. John Deere Co.* This secondary evidence must be evaluated and weighed along with evidence relied upon by the Office. *Stratoflex Inc. v. Aeroquip Corp.*, 713 F.2d 1530, 1538, 218 USPQ 871, 879 (Fed. Cir. 1983) and *In re Piasecki*, 745 F.2d 1468, 1471, 233 USPQ 785, 788 (Fed. Cir. 1984). Evidence of unobviousness can include evidence of superiority of a property shared with the art. MPEP § 716.02(a); *In re Chupp*, 816 F.2d 643, 646, 2 USPQ2d 1437, 1439 (Fed. Cir. 1987).

According to MPEP § 716.02(e), a declaration under 37 CFR § 1.132 must compare the claimed subject matter with the "closest prior art" to be effective to rebut a *prima facie* case of obviousness. It is improper for the Office to require a comparison of the claimed subject matter to subject matter that may result from a <u>combination</u> of references relied in the rejection of the claimed subject matter, because this "would be requiring comparison of the results of the invention with the

results of the invention." *In re Chapman*, 357 F.2d 418, 422, 148 USPQ 711, 714 (CCPA 1966); MPEP § 716.02(III).

B. Rejection of Claims 1-11, 13, 14 and 39-61 under 35 U.S.C. § 103(a) over Ni in view of Chang or Murugesh and Arami, Goodyear, or Ballance

1. Claims 1-6, 8-11, 13, 14, 39-43, 45-50, 56 and 58-61

a. The Claimed Subject Matter and Its Unexpected Advantges

The plasma processing system recited in Claim 1 comprises, *inter alia*, a gas injector comprising a body including an axial end surface exposed within the processing chamber, a side surface extending axially from the axial end surface, and a plurality of gas outlets including at least one on-axis outlet in the axial end surface and a plurality of spaced-apart off-axis outlets in the side surface. The off-axis outlets inject process gas at an acute angle relative to a plane parallel to an exposed surface of the substrate. A common gas supply is in fluid communication with a first gas line and a second gas line. The first gas line is in fluid communication with the on-axis outlet, but not with the off-axis outlets, and the second gas line is in fluid communication with the off-axis outlets, but not with the on-axis outlet. Flow controllers are operable to supply process gas from the common gas supply at flow rates that are independently varied between the on-axis outlet and the off-axis outlets into the processing chamber; and an RF energy source which inductively couples RF energy through the dielectric member.

The claimed plasma processing system advantageously provides tunable, multi-zone injection of process gas in the plasma processing chamber. The plasma

processing system provides improved process performance by allowing the adjustment (tuning) of the ratio of the gas flows through the respective on- and off-axis outlets of the gas injector (page 9, lines 8-29, of the present application). This flow ratio determines the convective flow field downstream from the nozzle tip. The convective flow field can be used to modify the total flow in the chamber, which also includes a diffuse flow component, thereby allowing the gas injector to modulate the spatial density dependence of reactive species.

Figures 3a-c illustrate the impact of the injector flow ratio on reactive species densities in an inductively-coupled plasma reactor including a gas injector 22 mounted in an opening in the window 20. *See* the paragraph bridging pages 13 to 14 of the present application. In the figures, increasing reactant density contours are shown by arrows A and increasing product density contours are shown by arrows B. Figure 3a shows the flow controllers set to direct the gas supply mostly through the on-axis outlet; Figure 3b shows the flow controllers set to direct the gas supply mostly through the off-axis outlets; and Figure 3c shows the gas flow ratio through the on-axis outlet and the off-axis outlets tuned to produce a mixed gas flow.

A Declaration by David J. Cooperberg Under 37 C.F.R. § 1.132 was submitted with the Amendment After Final Rejection filed on September 7, 2006. A copy of the Cooperberg Declaration is submitted herewith. The Cooperberg Declaration supports the unobviousness of the claimed subject matter.

In today's semiconductor manufacturing environment, it is necessary to vary gas compositions and flow rates during various fabrication steps, such as photoresist etch, hardmask open, ARC open, dielectric etch, trench etch and gate oxide etch. As discussed at paragraph 6 of the Cooperberg Declaration, most semiconductor

substrate etch processes include multiple, separate etch steps performed on a semiconductor substrate. Multiple steps of the processes are typically performed in the same plasma processing chamber. These different etch steps typically use different process gas compositions and different gas flow rate conditions. It is highly desirable to be able to optimize process performance for the different compositions and flow ratios. For example, to achieve a desired etch uniformity across a semiconductor wafer, different steps of a multi-step etch process may require different center- and edge-zone gas flow rates, i.e., different zone gas flow ratios, for the respective steps. These multi-step etch processes require the gas composition and/or flow ratio to be changed at least once, and typically numerous times, during the process, in a common chamber, to achieve the desired etch uniformity for different steps.

As discussed at paragraph 6 of the Cooperberg Declaration, the claimed tunable, multi-zone plasma processing system was designed to address the problem of providing a gas injector suitable for performing multiple steps of a multi-step process in a common plasma processing chamber including an RF energy source for inductively coupling RF energy into the chamber to produce a plasma, with optimized process uniformity for the different steps, and without the need for tool modification to perform the steps.

The claimed plasma processing system includes a gas injector that provides tunable, multi-zone gas injection, e.g., center zone and edge zone gas injection, in the plasma processing chamber. The claimed system includes an RF energy source, which is operable to inductively couple RF energy into the chamber to produce a plasma. The claimed gas injector has at least one on-axis outlet and a

plurality of off-axis outlets. The off-axis outlets inject process gas at an acute angle relative to a plane parallel to an exposed surface of a substrate supported on a substrate support within a processing chamber.

The claimed plasma processing system comprises a common gas supply in fluid communication with a first gas line in fluid communication with the on-axis outlet, but not with the off-axis outlets, and a second gas line in fluid communication with the off-axis outlets, but not with the on-axis outlet. As recited in Claim 1 (and Claims 7, 9, 10, 41 and 42), the term "common gas supply" means that the gas supply is adapted to supply the same gas composition to the first and second gas lines (or first and second gas passages, as recited in Claim 42). The same process gas composition supplied by the common gas supply to the first and second gas lines can be either a single gas, or a gas mixture. *See* page 12, lines 6-8, of the specification. The recited "common gas supply" is a structural feature.

The plasma processing system recited in Claim 1 comprises flow controllers operable to supply the process gas from the common gas supply at flow rates that are independently varied between the on-axis and off-axis outlets into the processing chamber. The claimed gas injector can vary the flow ratio of a common gas mixture supplied from the common gas supply through on- and off-axis outlets.

The gas injection capabilities of the claimed plasma processing system allow the gas flow ratio through the on- and off-axis outlets to be tuned to thereby optimize uniformity of one or more of the plasma and reactive species. The claimed system is adapted for different etch processes, and for different recipe steps within a multi-step etch process, which are performed in the plasma processing chamber and demand different on-axis to off-axis flow ratios for optimum uniformity. The claimed system

can provide optimized gas injection for a multi-step process with a single gas injector. As such, the claimed plasma processing system offers efficient and highly versatile performance, which renders it of great commercial utility in today's plasma etch chambers.

b. The Applied Prior Art

In accordance with *Graham v. John Deere Co.*, the scope and content of the prior art and differences between the prior art and the claims at issue will be addressed.

1. Ni

Ni corresponds to Lam's U.S. Patent No. 6,230,651. The Ni gas injection system shown in Figures 1 and 3A-3C of Ni includes a gas injector 22 connected to a gas supply 23. The gas injector 22 includes an on-axis gas outlet 46 and off-axis gas outlets 46 formed in the same bottom surface of the gas injector 22. As shown in Figures 3A and 3B of Ni, the side surface of the gas injector 22 is cylindrical shaped.

Each gas outlet 46 of Ni's gas injector 22 is supplied gas from the gas supply 23 via the bore 44. In Ni's gas injection system shown in Figures 1 and 3A-3C, because the on- and off-axis outlets 46 of the injector 22 are supplied gas from the same bore 44, the gas injection system cannot vary the gas flow rate through the on-axis outlet independently of the gas flow rate through the off-axis gas outlets. In other words, there is a fixed flow ratio of the gas flow rate through the on-axis gas outlet to the gas flow rate through the off-axis gas outlets in Ni's injector.

2. Chang

The gas delivery system shown in Figure 1 of Chang includes a top gas nozzle 96 in fluid communication with gas source 100a, and a top vent 98 surrounding the gas nozzle 96 and in fluid communication with the different gas source 100b. There are no gas outlets in a side surface of Chang's gas injector. Chang's apparatus also includes a gas ring 94 with side gas nozzles 106, 108 extending horizontally through the sidewall of the process chamber. As shown in Figure 1 of Chang, the same gas that is supplied to the top gas nozzle 96 is also supplied to the side gas nozzle 108, but a different gas is supplied to the top vent 98, to bifurcate the gas flow into two different flows (Chang at page 18, lines 14-16).

3. Murugesh

The embodiment of the gas distributor 215 shown in Figures 2A and 2B of Murugesh includes an inlet 218 for receiving a cleaning gas, which is distributed to gas outlets 247 opening at the top surface.

The gas distributor structure shown in Figure 3 of Murugesh is designed to direct different gases toward different surfaces (i.e., a substrate surface and an inner surface of the chamber wall) in order to both process substrates and clean the chamber. Murugesh's structure includes a first gas distributor 65 with first gas outlets 85 and a second gas distributor 215 with second gas outlets 247. Process gas 70 is supplied to the first gas outlets 85 from a first gas delivery system 60 and flowed in a downward direction toward a substrate to process a substrate. Cleaning gas is supplied to the second gas outlets 247 of the second gas distributor 215 from a second gas delivery system 200 (Murugesh at column 7, line 65, to column 8, line

26) and directed perpendicularly to the orientation of the first gas outlets 85 and toward the wall of chamber 30 to clean the chamber.

4. Goodyear

Goodyear is directed to an improvement over a gas supply arrangement discussed in its Background section in which "the same gas mixture is fed to both the peripheral and central areas [of a showerhead electrode], but at different rates . ..." (Goodyear at column 1, lines 20-53). Goodyear discloses that plasmas are "extremely complex and many of the details of physical and chemical interactions both within the plasma and with surfaces exposed to the plasma are not yet understood" (Goodyear at column 1, lines 54-57). Goodyear discovered that even if flow rates are controlled to peripheral and central areas of a showerhead electrode, "significant non-uniformities can still occur in the thickness, composition and quality of the deposited film" (Goodyear at column 1, lines 59-62). Goodyear states that such non-uniformities are more noticeable over large area substrates, and similar non-uniformities can occur in other plasma treatments such as plasma etching (Goodyear at column 1, lines 63-67). According to Goodyear, a common gas supply causes non-uniformity in plasma deposition and etching.

5. Ballance

Ballance discloses showerhead arrangements for rapid thermal processing (RTP). A high-intensity light source is used to heat a substrate and a process gas is used to deposit a film (Ballance at column 1, line 1 to column 2, line 62). Ballance also includes a discussion of an RF plasma etch system shown in Figure 8 of

Ballance (Ballance at column 8, lines 34-53). Ballance's system is identical to the system discussed in the Background section of Goodyear, i.e., a showerhead electrode including a central zone and peripheral zone supplied the same gas composition, but at different flow rates.

6. Arami

Arami discloses a showerhead-type gas injection arrangement. As shown in Figure 2, each of the gas supply sources 41, 42, 43 is in fluid communication with all three of the gas chambers 37A, 37B, 37C. Arami at column 4, lines 43-49.

c. *Prima Facie* Obviousness Has Not Been Established

To establish a *prima facie* case of obviousness, all claim limitations must be taught or suggested by the prior art. *See* MPEP § 2143.03. As set forth in MPEP § 2143.03(VI), "a prior art reference must be considered in its entirety, i.e., as a whole, including portions that would lead away from the claimed invention." (Citation omitted.) The applied combination of references does not suggest the claimed plasma processing system, as a whole, comprising, *inter alia*, a gas injector including at least one on-axis gas outlet in an axial end surface and a plurality of spaced-apart off-axis gas outlets in the side surface, which off-axis gas outlets inject process gas at an acute angle relative to the plane parallel to the exposed surface of the substrate; and a common gas source in fluid communication with (a) a first gas line in fluid communication with an on-axis outlet, and (b) a second gas line in fluid communication with off-axis outlets.

Ni's gas injection system shown in Figures 1 and 3A-3C does not include the following features of Claim 1:

(1) a gas injector including at least one on-axis gas outlet in an axial end surface and a plurality of spaced-apart off-axis gas outlets in the side surface, which inject process gas at an acute angle relative to the plane parallel to the exposed surface of the substrate;

(2) a common gas supply in fluid communication with a first gas line and a second gas line, where the first gas line is in fluid communication with at least one on-axis outlet but not with off-axis outlets formed in a gas injector body, and the second gas line is in fluid communication with the off-axis outlets but not with the on-axis outlet; and

(3) flow controllers operable to supply process gas from the common gas supply at flow rates that are independently varied between the on-axis outlet and the off-axis outlets into the processing chamber.

Thus, there are multiple, substantial structural and functional differences between the claimed system and Ni's system shown in Figures 1 and 3A-3C. Therefore, one having ordinary skill in the art would have had to extensively reconstruct Ni's system to produce the claimed plasma processing system.

Regarding this needed extensive reconstruction of Ni, the Examiner states: "with respect to applicant's argument that the modification of Ni et al. would require extensive engineering design if the references were combined as suggested, the test for obviousness is not whether the features of a secondary reference may be bodily incorporated into the structure of the primary reference." However, the substantial structural and functional differences between Ni's system and the claimed system

are pertinent to the question of what the combined teachings of the applied references would have suggested to those of ordinary skill in the art.

Ni's gas injection system is designed for a specific purpose, i.e., to provide improved uniformity for an etch process step. To be able to achieve this intended purpose, the Ni gas injector supplies a fixed gas flow ratio for the different gas outlets. Ni fails to recognize the etch uniformity problem solved by the claimed plasma processing system with respect to a multi-step etch process. Ni discloses that "the gas injector in accordance with the invention can improve etch uniformity, center-to-edge profile uniformity, critical dimension (CD) bias and/or profile microloading" (Ni at page 8, lines 13-15; emphasis added). Ni discloses that "improved etch results can be achieved with a single gas injector located centrally in the upper chamber wall" (Ni at page 8, lines 21-22), and that "[t]he number of gas outlets and/or the angle of injection of gas flowing out of the gas outlets can be selected to provide desired gas distribution in a particular substrate processing regime" (Ni at page 9, lines 1-3). The effects on gas distribution of the Ni gas injector compared to a gas ring are shown in Figures 2a and 2b of Ni. Figure 4 of Ni shows that the gas injector provides more uniform etch by-product distribution above the exposed surface of a 300 mm wafer as compared to side gas injection (Ni at page 11, lines 16-23). Thus, Ni discloses that the gas injector provides improved uniformity when used for its designed purpose.

However, one skilled in the art would not have been informed of the uniformity problem addressed by the claimed subject matter by reading Ni's disclosure. Ni's gas injector is unable to provide etch uniformity in different steps of a multi-step etch process using the same injector, because the gas injector is designed to produce

certain etching results for a particular substrate etch process. While Ni recognizes that "depending on the etching process, the number of gas outlets, the location of the gas outlets such as on the axial end and/or the sides of the gas injector as well as the angle(s) of injection of the gas outlets can be selected to provide optimum etching results" (Ni at page 14, lines 11-14), these structural changes of the gas injector are only made to make Ni's injector more suitable for a specific etch step.

For instance, Ni discloses that etching of aluminum may require directing the etch gas away from a substrate being etched, while polysilicon etching may require directing the process gas towards the substrate (Ni at page 14, lines 3-9). Ni discloses that the gas injector can be specially designed to have one construction (with no central gas outlet in the axial end) when used for aluminum etching (Ni at page 14, lines 16-23), while the gas injector can be specially designed to have a substantially different construction (including a central gas outlet) when used for polysilicon etching (Ni at the paragraph bridging pages 14 to 15). Ni does not suggest designing the gas injector so that it can provide optimal etch results for aluminum and polysilicon etch steps, but teaches that different gas injectors with different respective structures are needed to perform these different etch steps.

Because the Ni gas injector structure shown in Figures 1 and 3A-3C is only designed for a single process step, it would be necessary to use multiple Ni injectors, each with a different structure, in the same processing chamber, to be able to make one or more gas flow ratio changes in a multi-step process. This limitation of the Ni injector makes it commercially impractical for performing multi-step processes. Cooperberg Declaration at paragraph 11.

In contrast to Ni's injector shown in Figures 1 and 3A-3C, the claimed gas injector is constructed for performing various etching processes in the same plasma processing chamber. In a multi-step process in which improved etching uniformity may require changes in the distribution of the etch gas in the chamber, the claimed injector allows adjustable gas distribution to maintain the desired etch uniformity in each sub-step of a multi-step process. The Ni gas injector lacks such adjustment capability because the flow ratio through the off-axis and on-axis outlets cannot be independently adjusted. Thus, the problem solved by Appellants' gas injection system is not recognized in Ni. Moreover, the claimed injector provides substantially improved results as compared to the Ni injector.

Appellants submit that the Examiner has not articulated why one skilled in the art would have possessed the knowledge and reason to make the claimed subject matter. The Ni injector is useful for certain processes that use a fixed flow pattern for an entire etching step. Cooperberg Declaration at paragraphs 3 and 5. The Ni injector does not provide required uniformity standards for certain multi-step etch processes wherein the gas composition and flow rates are varied. Cooperberg Declaration at paragraphs 3 and 5. Whereas the Ni injector requires extensive engineering design and experimentation to achieve a fixed flow pattern for one particular etch step (Cooperberg Declaration at paragraph 5), a single design of the claimed injector can be used to meet uniformity standards in a variety of multi-step processes, because the injector permits adjustment of flow rates to center and edge regions of a substrate. The Ni injector can only be designed to meet uniformity standards for a sub-step of such multi-step process, which makes the injector impractical for a multi-step process.

The combination of references applied by the Examiner does not support the alleged *prima facie* case of obviousness of the claimed subject matter, considered as a whole. The Examiner's proposed modification of Ni's injector would have required the injector to be substantially reconstructed to include on-axis and off-axis outlets and separate gas lines supplying such outlets, despite that fact that Ni's gas injector is designed for the specific purpose of performing a single etch step. For reasons discussed below, the applied prior art: (a) does not disclose or suggest every claimed feature; (b) does not recognize the problem that was recognized and solved by the inventors; (c) includes disclosures that explicitly teach away from the proposed modification of Ni; (d) does not suggest the desirability of modifying Ni in the manner proposed in the final Official Action; and (e) does not establish a reasonable expectation of success.

As further explained in the Cooperberg Declaration, the claimed injector provides superior results compared to the Ni injector. Such superior results must be weighed against the alleged *prima facie* case of obviousness.

1. Chang and Murugesh Do Not Suggest a Gas Injector Having On- and Off-Axis Gas Outlets For Supplying the Same Gas Into a Processing Chamber

Each of Chang and Murugesh discloses a gas injector including on- and off-axis gas outlets in fluid communication with different respective gas sources for supplying different gases into a processing chamber. Chang supplies one gas from a first gas supply through the gas nozzle 96 and the side gas nozzle 108, and a different gas from a second gas supply through the top vent 98. Chang does not disclose or suggest a gas injection system that (1) supplies the same gas from a

common gas supply to all on- and off-axes of a gas injector, or (2) can vary the flow ratio of that gas supplied from the on- and off-axis outlets into a processing chamber. Chang provides a gas injector (including gas nozzle 96 and top vent 98) with different outlets to be able to supply different gases into the chamber. Chang does not suggest any reason to have the gas nozzle and top vent in the same gas injector for supplying only one gas into the chamber. In contrast, Chang would have taught one skilled in the art that only one of the outlets 96, 98 would be desirable. Thus, Chang would not have suggested modifying Ni's gas injector shown in Figures 1 and 3A-3C to enable the injector to supply the same gas from a common gas supply via on- and off-axis outlets, much less at a variable flow ratio.

Murugesh also does not suggest a gas injection system that (1) supplies the same gas from a common gas supply to all on- and off-axis of a gas injector, or (2) can vary the flow ratio of that same gas supplied from the on- and off-axis outlets into a processing chamber. In contrast, Murugesh's injector includes different outlets in communication with different respective gas sources to be able to supply different gases to different locations in the chamber, for different purposes. Murugesh discloses that the embodiment of the injector shown in Figure 3 is advantageous "when it is desirable to locate both the process gas outlets 85 and the cleaning gas outlets 247 near each other in the chamber 30" (column 8, lines 2-5; emphasis added). Murugesh does not suggest that it would have been desirable to have the gas outlets 85 and 247 in the gas injector to supply only one gas into the chamber. In contrast, Murugesh would have taught one skilled in the art that only one of the outlets 85, 247 would be desirable. Thus, Murugesh does not suggest (1) supplying the same gas to on- and off-axis gas outlets of a gas injector; (2) optimizing the flow

ratio of that same gas to such on- and off-axis gas outlets for a given step of a multi-step process; or (3) changing the flow ratio of the same gas supplied by on- and off-axis gas outlets for different steps of such multi-step process to optimize process results for the different steps and thus for the overall process.

Thus, Chang and Murugesh both fail to provide any reason for modifying Ni's gas injector to include on- and off-axis gas outlets that supply the same gas into a processing chamber, much less with gas tuning features.

2. One Skilled in the Art Would Not Have Looked to the Goodyear, Ballance or Arami Showerhead Electrodes to Modify Ni's Gas Injector

To attempt to remedy the substantial deficiencies of Ni, Chang and Murugesh with regard to the claimed subject matter, the Examiner also looked to the showerhead electrode art, as exemplified by Arami, Goodyear and Ballance. Appellants submit that one skilled in the art, in light of the explicit disclosure of Ni and the knowledge in the art regarding the different structure, purpose and performance characteristics of showerhead electrodes, would not have considered the showerhead art to attempt to modify Ni's gas injector, which is not a showerhead electrode.

First, Ni states that "[a]ccording to the invention, instead of using a gas ring or showerhead to supply process gas into the chamber, the gas injector is mounted in an opening extending through the dielectric window" (emphasis added). Ni at page 9, lines 13-15. Accordingly, Ni's gas injector is designed to be used in the processing chamber instead of a showerhead, and in an entirely different manner

than a showerhead. As such, Ni would have led one skilled in the art away from the showerhead art.

As stated in *KSR*, "when prior art teaches away from combining certain known elements, discovery of a successful means of combining them is more likely to be nonobvious." *KSR* at 82 USPQ2d 1395. However, the Office appears to have completely disregarded this explicit teaching away by Ni and relied on isolated disclosures in the showerhead art to try to justify the substantial reconstruction of Ni's non-showerhead injector to try to produce the claimed subject matter. Because the Examiner disregarded this evidence, which weighs against the *alleged prima* facie obviousness, the rejection is not consistent with *KSR*.

Second, it is well-known in the art of semiconductor plasma processing that showerhead electrodes are designed to have particular constructions and performance characteristics to enable them to be used in capacitively-coupled plasma reactors. As discussed at paragraph 13 of the Cooperberg Declaration, showerhead-type gas injectors typically have substantially different numbers of gas injection holes, are positioned differently with respect to wafers in plasma processing chambers, and provide substantially different gas flow characteristics due to their construction and positioning in the chamber, as compared to the claimed gas injector. The claimed gas injector is used in an inductively-coupled (ICP) plasma processing system, not in a capacitively-coupled system. Showerhead electrodes typically include 1000 or more outlets; are conductive and cannot be used beneath a coil in an ICP system; are normally positioned much closer to a wafer; and normally provide a sufficiently low gas velocity such that diffusion is the dominant transport mechanism in a processing chamber. Because of these substantial structural and

functional differences, it is Mr. Cooperberg's opinion that one having ordinary skill in the art would not have selected references in the showerhead electrode art to modify the Ni gas injector, which is used in an ICP system. This opinion testimony, which is based on well-known differences in the art and reflects the knowledge in the art, is entitled to consideration by the Office. *See* MPEP § 716.01.

Mr. Cooperberg's opinion is also consistent with the explicit disclosure in Ni that showerhead electrodes are a different type of gas injection system used for their own different performance characteristics.

3. Goodyear, Ballance and Arami do not Cure the Deficiencies of Ni in view of Chang or Murugesh

Moreover, even if the showerhead electrodes of Arami, Goodyear and Ballance are also considered, these references still fail to suggest substantially reconstructing Ni's gas injection system for various reasons. For example, these references do not suggest modifying Ni because showerhead electrodes are electrically conductive and unsuitable for use in ICP systems. Cooperberg Declaration at paragraph 13.

Also, each of the Arami, Goodyear and Ballance showerhead electrodes has only on-axis outlets, i.e., no off-axis outlets. The large numbers of on-axis outlets in the showerhead electrodes are located close to the wafer being processed to be able to direct process gas directly at the wafer in a "blanket." As such, these references do not cure the deficiencies of Ni. The Office has provided no objective teaching or evidence of knowledge in the art of the claimed plasma processing system comprising a common gas source in fluid communication with (1) a first gas

line in fluid communication with an on-axis outlet and (2) a second gas line in fluid communication with off-axis outlets.

Furthermore, Goodyear explicitly teaches away from an arrangement including a common gas supply, as follows:

> If an identical gas composition is fed via the lines 21 and 22, the present inventors find that (even with adjustment of different flow rates in the separate supply lines 21 and 22) significant depletion of one reaction gas can occur in the plasma reaction in the gas phase and at the surface of the device substrate 4(14) at a peripheral area of a large area electrode 11, and so non-uniform deposition or etching occurs over the total area (emphasis added). Goodyear at column 4, lines 48-56.

See also paragraph 12 of the Cooperberg Declaration. According to Goodyear, if an identical gas composition is fed via the lines 21 and 22, significant depletion of a reaction gas occurs in the chamber, resulting in non-uniform deposition or etching (Goodyear at column 4, lines 48-56). According to Goodyear, "[i]n many cases, severe process non-uniformities result if the present invention is not employed" (column 4, lines 63-64). Goodyear is directed to solving a problem caused by use of a common gas source in a showerhead electrode. According to Goodyear, the problem is that use of a common gas source causes non-uniform deposition or etching due to depletion of a gas composition ingredient. As such, Goodyear discourages and criticizes the use of a common gas source that inherently supplies the same gas composition to separate gas lines in fluid communication with separate zones of a showerhead electrode. According to Goodyear, to achieve uniformity, it is necessary to use different gas sources, i.e., not the same gas composition, for each respective zone of the showerhead electrode. While Goodyear explicitly teaches that using a common gas source causes non-uniform

deposition or etching, one skilled in the art of semiconductor substrate processing would try to achieve greater uniformity, not less. Thus, one skilled in the art would have been discouraged from using a common gas source for multiple zones of a showerhead electrode.

A reference that criticizes, discredits or otherwise discourages a claimed solution, teaches away from that solution. *In re Fulton*, 391 F.3d at 1144, 73 USPQ2d at 1146. Because Goodyear expressly criticizes, discredits and discourages supplying the same composition to different zones of a showerhead electrode, Goodyear fails to provide the requisite motivation for modifying the structure of Ni's gas injection system as proposed by the Examiner.

Despite Goodyear's explicit teaching away from the use of common gas supply, the Examiner states "[w]ith respect to applicant's argument concerning Goodyear explicitly teaching against a common gas supply which would supply an identical gas composition to the gas lines, the examiner respectfully disagrees with such a statement . ..." (Emphasis added.) Final Official Action at page 8, last paragraph.

However, the Examiner does not articulate any reason why Appellants' interpretation of Goodyear's disclosure is incorrect and Goodyear does not teach away from the claimed common gas supply. As stated in *In re Mercier*, 515 F.2d 1161, 1166, 185 USPQ 774, 778 (CCPA 1975):

> The relevant portions of a reference include not only those portions which would suggest particular aspects of an invention to one having ordinary skill in the art, but also those teachings which would lead away from the clamed invention (emphasis added; citation omitted).

> The board's approach amounts, in substance, to nothing more than a hindsight "reconstruction" of the claimed invention by relying on isolated teachings of the prior art without considering the over-all context within which those teachings are presented. Without the benefit of appellant's disclosure, a person having ordinary skill in the art would not know what portions of the disclosure of the reference to consider and what portions to disregard as irrelevant, or misleading (emphasis added; citation omitted).

The Examiner failed to consider all relevant portions of Goodyear, and improperly disregarded explicit teachings of Goodyear that would have led away from the claimed subject matter. The Examiner also failed to consider that the inventor successfully incorporated a common gas supply into the claimed subject matter. The inventor's discovery weighs against the alleged *prima facie* obviousness. *KSR*, 82 USPQ2d at 1395.

Furthermore, Ballance and Arami also fail to cure the deficiencies of Ni and Chang or Murugesh. Ballance discloses an RTP system for non-plasma deposition. Figure 8 of Ballance shows a showerhead 300 that supplies gas to an inner chamber 308 and an outer chamber 306. However, Goodyear teaches that the type of showerhead electrode system disclosed by Ballance produces undesired non-uniformity results unless separate gas sources are used.

Arami's apparatus shown in Figure 2 includes a showerhead with gas chambers 37A, 37B and 37C. The three gas chambers 37A, 37B and 37C are not in fluid communication with only a common gas supply. In stark contrast, each of these gas chambers is in fluid communication with all three gas supply pipes 38, 39 and 40, and each gas supply pipe 38, 39 and 40 is, in turn, in fluid communication with all three gas supplies 41, 42 and 43. Arami does not suggest any embodiment in which each gas supply 41, 42, 43 is not in fluid communication with each gas chamber

37A, 37B and 37C. Accordingly, Arami does not suggest the Examiner's hindsight reconstruction of Ni's gas injector

As set forth in MPEP § 2145(X)(D)(2), "it is improper to combine references where the references teach away from their combination." (Citation omitted.) Thus, because Ni explicitly teaches away from showerheads, and Goodyear explicitly teaches away from using a common gas supply, the rejection over Ni in view of Chang or Murugesh and Arami, Goodyear or Ballance is untenable because the applied references teach away from the combination advanced by the Examiner.

Also, the applied references do not provide a solution to the problem of achieving uniformity during sub-steps of a multi-step etch process in a plasma processing chamber including an RF energy source for inductively coupling RF energy into the chamber to produce a plasma. This problem was solved by the claimed plasma processing system.

Thus, because the applied combination of references does not support the alleged *prima facie* obviousness, the system recited in Claim 1 is patentable.

Independent Claim 9 recites a plasma processing system comprising, *inter alia*, a gas injector "including off-axis gas outlets which inject process gas at an acute angle relative to the plane parallel to the exposed surface of the substrate, the off-axis outlets being circumferentially spaced apart from each other"; and a "common gas supply."

Independent Claim 41 recites a plasma processing system comprising, *inter alia*, a gas injector body including "a plurality of off-axis outlets which inject process gas at an acute angle relative to a plane parallel to an exposed surface of the substrate"; and a "common gas supply."

Independent Claim 42 recites a plasma processing system comprising, *inter alia*, a gas injector comprising "second gas outlets [in the side surface of the gas injector which] inject process gas at an acute angle relative to a plane parallel to an exposed surface of the substrate"; and a "common gas supply."

Thus, the applied combination of references also does not support the alleged *prima facie* obviousness with respect to Claims 9, 41 and 42.

d. Secondary Evidence of Nonobviousness

1. Present Application and Cooperberg Declaration

The present application and the Cooperberg Declaration demonstrate the existence of the problem of achieving, with a single injector, optimized process uniformity in a multi-step process that requires different gas flow ratios for different steps of the process, and that the claimed subject matter provides a solution to this problem. The Examiner's reasons for not giving the Cooperberg Declaration adequate weight are without foundation.

Particularly, the present application includes evidence of the uniformity problem that occurs when using the Ni injector shown in Figures 1 and 3A-3C and establishes that the claimed tunable, multi-zone gas injector can provide properties not present in Ni. More particularly, the Examples described at pages 19-21 of the present application show results that can be provided by embodiments of the claimed plasma processing system, but not by the Ni gas injection system, which cannot provide adjustable, multi-zone gas flow via on-axis and off-axis gas outlets of the gas injector, and thus does not allow the gas flow ratio between the on-axis and

off-axis outlets to be changed during a multi-step process to optimize process uniformity.

Furthermore, as discussed at paragraphs 8-11 of the Cooperberg Declaration, Examples 1 to 3 show that the flow ratio of the gas flows from the on- and off-axis gas outlets, i.e., predominately off-axis flow, predominately on-axis flow, or mixed on-axis and off-axis flow, that provides optimal results for a given process (which can be a step of a multi-step etch process for a semiconductor substrate) can be substantially different from gas flow ratios that provide the most desirable plasma etch results for other processes performed in a processing chamber (such as different step of a multi-step etch process).

The test results for Examples 1 to 3 summarized in Table 1 of the Cooperberg Declaration indicate that the best results were achieved by the claimed plasma processing system in the polysilicon etch process of Example 1 using a <u>mixed gas flow</u>, but the best results were achieved by the claimed plasma processing system in both the silicon etch process of Example 2 and polysilicon gate etch process of Example 3 using <u>predominately off-axis</u> gas flow settings.

The comparative test results described in the present application show that the claimed plasma processing system provides optimized process uniformity in a multi-step process that requires different gas flow ratios for different steps of the process. The comparative test results also provide evidence that the Ni gas injector shown in Figures 1 and 3A-3C, which <u>cannot</u> change the gas flow ratio between its on-axis and off-axis outlets, cannot provide optimized process uniformity for process steps of a multi-step process that require a different gas flow ratio than the single gas flow ratio that the Ni gas injector is designed to provide.

As also discussed in the Cooperberg Declaration, even assuming that the Ni injector can supply a mixed gas flow ratio that provides optimal process results for the process of Example 1, the same Ni injector design could not also provide optimized process results for the processes of Examples 2 and 3, because these processes both require different, predominately off-axis flow conditions to achieve optimal process uniformity. As further discussed in the Cooperberg Declaration, assuming alternatively that the Ni injector can be designed to supply a predominately off-axis gas flow that provides optimal results for the processes of Example 2 and 3, the same Ni injector would not also provide optimized process results for the process of Example 1. In fact, the Example 1 process off-axis flow conditions provide the worst process uniformity of the three settings.

The comparative data demonstrates the superiority of the claimed plasma processing system with respect to its ability to provide tunable, multi-zone gas injection, which makes the system advantageous for today's multi-step processes, which normally require gas flow ratios and/or compositions to be changed multiple times during a given process. This superiority is sufficient to constitute unexpected results. *In re Chupp*, 816 F.2d at 646, 2 USPQ2d at 1439.

2. The Office Has Not Established that the Improved Gas Flow Performance of the Claimed Subject Matter Would Have Been Expected

Despite the above-discussed evidence of improved gas flow performance of the claimed subject matter, the final Official Action contends that "[i]t would have been expected that added controllability to the injector of Ni et al. would allow for

improved controllability and better results with respect to different etching processes, as shown by the declaration (emphasis added).

Although the Examiner admitted that Appellants have established evidence of "improved" results that distinguish the claimed subject matter over the closest prior art, the Examiner characterized these improved results as merely "expected."

First, as discussed above, showerhead electrodes and gas injectors have very different structures and performance characteristics with respect to the gas flows that they provide. In light of these differences, the Examiner has not articulated a reason to support the position that the proposed structural changes of Ni's gas injector in light of the applied showerhead electrodes would have predictable results.

Second, it appears that the Examiner evaluated Appellants' rebuttal evidence against the conclusion of obviousness itself, rather than against the facts on which the conclusion of obviousness was based. It is improper to treat the alleged *prima facie* case of obviousness as if it were "set in concrete." *In re Piasecki*, 745 F.2d at 1473, 223 USPQ 785, 788 (Fed. Cir. 1984).

Third, evidence of superior results must compare the claimed subject matter only with the closest prior art reference, i.e., only with Ni, and not with the applied combination of references or with prior art that does not exist. *In re Chapman*, 357 F.2d at 422, 148 USPQ at 714. Ni's gas injector provides no adjustability or control with respect to the gas flow ratio between the on-axis and off-axis gas outlets.

None of the references cited by the Examiner suggests the improved etch uniformity for multi-step etch processes that is provided by the claimed gas injection system. In *In re Adams*, 356 F.2d 998, 148 USPQ 742 (CCPA 1966), the court

considered the patentability of an invention that used foam to cool containers and provided increased heat transfer efficiency where the applied prior art provided no teaching of this improvement. The court stated:

> The Patent Office presents a number of hindsight arguments. It says Adams was not the first to *use* foam for *heat transfer* as fire departments and fire extinguisher users have been squirting foam on fires for years and housewives have been pouring aerated hot water on cold plates for years, in both of which operations heat transfer is *inherent*. Of course it is inherent, otherwise appellant's invention would not work. But patentability here does not hinge on inherency. It depends on the unexpected and unsuggested increase in heat transfer *efficiency*. No reference suggesting this has been produced, only ex post facto explanations as to why anyone should have been able to see that it would be more efficient to use aerated water (emphasis added). *Adams* at 356 F.2d 1002, 148 USPQ 746.

Like in *Adams*, the Examiner appears to have taken an inherency position and provided no evidence supporting the alleged "expected results." Ni does not suggest that the claimed system would provide improved controllability and better results with respect to different etching processes because Ni provides no gas tuning capabilities. Thus, Ni provides no suggestion regarding the "expected" gas flow characteristics of the claimed system. The Examiner has cited no additional evidence to support the alleged inherency.

Thus, the Examiner has not established that the results provided by the claimed subject matter would have been expected.

3. The Present Inventors Recognized the Problem Solved by the Claimed Subject Matter

The Examiner states:

> Furthermore, a portion of the declaration states that the claimed subject matter solved a problem that was long standing in the art, and that the inventor discovered the source of the

> problem (see item 4). However, there is no showing that others of ordinary skill in the art were working on the problem and if so, for how long. (Emphasis added.)

At paragraph 4 of the Cooperberg Declaration, Mr. Cooperberg stated:

> In today's semiconductor manufacturing environment, it is necessary to vary gas compositions and flow rates during different fabrication steps in multi-step processes. Such steps can include, for example, ARC etch, photoresist etch, hardmask open, trench isolation and gate etch, which can be performed on a single substrate (wafer) in the same plasma processing chamber. <u>During development of the present invention, it was found that the Ni injector would not meet the uniformity standards for such multi-step etch processes, wherein the gas composition and/or flow ratio is changed at least once</u>. (Emphasis added.)

As stated by Mr. Cooperberg, the present inventors recognized during development of the claimed gas injection system that Ni's gas injector would not meet uniformity standards for multi-step etch processes. The inventors developed the claimed gas injection system to address this uniformity problem in multi-step etch processes. The recognition and solution of a problem, as well as the discovery of a source of a problem, are part of the "subject matter as a whole" analysis under 35 U.S.C. § 103. *See* MPEP § 2141.02(III).

4. Appellants Are Not Required to Claim Superior Results Provided by the Claimed Subject Matter <u>To Rely on Them to Establish Unobviousness</u>

The Examiner asserts the following:

> Concerning the argument that Ni et al. is not concerned with achieving uniformity in different steps of a multi-step process using the same injector, it is noted that <u>the features upon which applicant relies</u> (i.e., achieving uniformity in different steps of a multi-step etch process using the same injector) are not recited in the rejected claim(s). Although the claims are interpreted in light of the specification, limitations from the specification are not read into the claims. (Final Official Action at page 10, lines 8-14; Citation omitted.)

The Examiner appears to contend that Appellants cannot rely on certain superior results provided by the claimed subject matter (achieving uniformity in different steps of a multi-step etch process using the same injector) if these results are not expressly recited in the claims. Because the Examiner's position is contrary to legal precedent, Appellants respectfully disagree. As set forth in *In re Merchant*, 575 F.2d 865, 869, 197 USPQ 785, 788 (CCPA 1978):

> Finally, the solicitor repeats the objection voiced by the examiner that the declaration is irrelevant because the claims specify neither the unexpected result nor the 'features' that produce that result. We are aware of no law requiring that unexpected results relied upon for patentability be recited in the claims. We are equally unaware of any law requiring that commercial production parameters be claimed. Moreover, the feature responsible for appellant's unexpected results is recited in the claims .... (Emphasis added).

The features of the claimed plasma processing system that are responsible for the superior results are recited in the claims. According to *Merchant*, Appellants are not required to claim the superior results provided by the claimed plasma processing system. Thus, it is improper for the Office to not give proper weight to Appellants' showing.

Therefore, the Board is respectfully requested to reverse the rejection of Claims 1-6, 8-11, 13, 14, 39-43, 45-50, 56 and 58-61.

2. Claims 7, 44 and 57

Independent Claim 7 recites a plasma processing system comprising, *inter alia*, a gas injector including a planar axial end face having an on-axis outlet therein and a conical side surface having off-axis outlets therein, where the on-axis outlet receive process gas from a central passage in the injector and the off-axis outlets

receive process gas from an annular passage surrounding the central passage, the gas injector supplies process gas at flow rates that are independently varied between the on-axis outlet and the off-axis outlets into the processing chamber. The system also comprises a common gas supply in fluid communication with first and second gas lines, where the first gas line is in fluid communication with the on-axis outlet but not with the off-axis outlets and the second gas line is in fluid communication with the off-axis outlets but not with the on-axis outlet. (Emphasis added.)

The word "conical" means shaped like a cone. The outer diameter of the gas injector shown in Figures 2a-2c is defined by the side surface, which increases continuously in the axial direction from the axial end surface (i.e., bottom surface). This increase in diameter of the gas injector in the axial direction is consistent with the meaning of the term "conical." The final Official Action contends that Ni's gas injector 22 has conical or cylindrical side surfaces (final Official Action at page 3, lines 7-8). Ni does not support this assertion.

The Examiner identified no disclosure in Ni of a gas injector having a "conical" side surface, much less also having off-axis outlets in such "conical" side surface. In fact, Ni discloses that the gas injector 22 has a "cylindrical body." Ni at page 11, lines 7-8. Appellants also note that Ni discloses a "conical liner 30." (Ni at page 10, lines 3-4.) As shown in Figure 1 of Ni, as consistent with the meaning of the work "conical," the conical liner 30 has an increasing diameter in the vertically downward direction from the window 20. Ni does not disclose or suggest any gas injector 22 having a "conical" outer surface, as this term should be properly understood. Absent

any disclosure in Ni of a gas injector with a conical side surface, there is no basis for the ground of rejection of Claim 7 for this additional reason.

Therefore, the Board is respectfully requested to also reverse the rejection of Claims 7, 44 and 57.

3. Claims 51-55

Claims 51-55 depend from Claims 1, 7, 9, 41 and 42, respectively. Each of Claims 51-55 recites, *inter alia*, the features of "the common gas supply is a gas mixture." The applied combination of references does not suggest modifying Ni to include a common gas supply.

In addition, the applied combination of references does not suggest modifying Ni to include a common gas supply that is a gas mixture. For example, the final Official Action contends that Arami discloses a "common gas supply" 41 (final Official Action at page 11, lines 14-19). To the extent that the gas supply source 41 is a "common gas supply," it supplies SiH_4, not a gas mixture. To provide a gas mixture, Arami's system must supply gas from multiple gas supply sources.

Therefore, the Board is respectfully requested to also reverse the rejection of Claims 51-55.

C. Rejection of Claim 15 under 35 U.S.C. § 103(a) over Ni and Chang or Murugesh and Arami, Goodyear or Ballance, and Powell

Claim 15 depends from Claim 1. Powell has been applied in the rejection for allegedly disclosing an electrically conducting shield. Powell also fails to cure the above-described deficiencies of Ni with respect to the subject matter recited in Claim 1. At the least, Powell also does not suggest a gas injector "comprising a body

including an axial end surface exposed within the processing chamber, a side surface extending axially from the axial end surface, and a plurality of gas outlets including at least one on-axis outlet in the axial end surface and a plurality of spaced-apart off-axis outlets in the side surface," as recited in Claim 1.

Therefore, the Board is respectfully requested to also reverse the rejection of Claim 15.

VIII. Claims Appendix

See the attached Claims Appendix for a copy of the claims involved in the appeal.

IX. Evidence Appendix

See the attached Evidence Appendix.

X. Related Proceedings Appendix

See the attached Related Proceedings Appendix.

XI. Conclusion

For the foregoing reasons, reversal of the rejections of Claims 1-11, 13-15 and 39-61 is respectfully requested.

Respectfully submitted,
BUCHANAN INGERSOLL & ROONEY PC

Date: June 13, 2007

By: ______________________
Edward A. Brown
Registration No. 35,033

Table of Contents

VIII. CLAIMS APPENDIX

The Appealed Claims

1. (Previously Presented) A plasma processing system comprising:

a plasma processing chamber;

a vacuum pump connected to the processing chamber;

a substrate support on which a substrate is processed within the processing chamber;

a dielectric member having an interior surface facing the substrate support, wherein the dielectric member forms a wall of the processing chamber;

a gas injector extending through the dielectric member, the gas injector comprising a body including an axial end surface exposed within the processing chamber, a side surface extending axially from the axial end surface, and a plurality of gas outlets including at least one on-axis outlet in the axial end surface and a plurality of spaced-apart off-axis outlets in the side surface, the off-axis outlets inject process gas at an acute angle relative to a plane parallel to an exposed surface of the substrate;

a common gas supply in fluid communication with a first gas line and a second gas line, the first gas line being in fluid communication with the on-axis outlet but not with the off-axis outlets and the second gas line being in fluid communication with the off-axis outlets but not with the on-axis outlet;

flow controllers operable to supply process gas from the common gas supply at flow rates that are independently varied between the on-axis outlet and the off-axis outlets into the processing chamber; and

an RF energy source which inductively couples RF energy through the dielectric member and into the chamber to energize the process gas into a plasma state to process the substrate.

2. (Original) The system of Claim 1, wherein the system is a high density plasma chemical vapor deposition system or a high density plasma etching system.

3. (Original) The system of Claim 1, wherein the RF energy source comprises an RF antenna and the gas injector injects the process gas toward a primary plasma generation zone in the chamber.

4. (Previously Presented) The system of Claim 1, wherein the first gas line is in fluid communication with an axially extending central bore in the injector body, and the second gas line is in fluid communication with an annular gas passage surrounding the central bore.

5. (Previously Presented) The system of Claim 1, wherein the injector body is cylindrical shaped and the off-axis outlets are circumferentially spaced apart.

6. (Original) The system of Claim 1, wherein the gas injector injects the process gas at a subsonic, sonic, or supersonic velocity.

7. (Previously Presented) A plasma processing system comprising:

a plasma processing chamber;

a vacuum pump connected to the processing chamber;

a substrate support on which a substrate is processed within the processing chamber;

a dielectric member having an interior surface facing the substrate support, wherein the dielectric member forms a wall of the processing chamber;

a gas injector extending through the dielectric member such that a distal end of the gas injector is exposed within the processing chamber, the gas injector including a planar axial end face having an on-axis outlet therein and a conical side surface having off-axis outlets therein, the on-axis outlet receiving process gas from a central passage in the injector and the off-axis outlets receiving process gas from an annular passage surrounding the central passage, the gas injector supplying process gas at flow rates that are independently varied between the on-axis outlet and the off-axis outlets into the processing chamber;

a common gas supply in fluid communication with a first gas line and a second gas line, the first gas line being in fluid communication with the on-axis outlet but not with the off-axis outlets and the second gas line being in fluid communication with the off-axis outlets but not with the on-axis outlet; and

an RF energy source which inductively couples RF energy through the dielectric member and into the chamber to energize the process gas into a plasma state to process the substrate.

8. (Original) The system of Claim 1, wherein the gas injector is removably mounted in the dielectric window and supplies the process gas into a central region of the chamber.

9. (Previously Presented) A plasma processing system comprising:

a plasma processing chamber;

a vacuum pump connected to the processing chamber;

a substrate support on which a substrate is processed within the processing chamber;

a dielectric member having an interior surface facing the substrate support, wherein the dielectric member forms a wall of the processing chamber;

a gas injector extending through the dielectric member such that a distal end of the gas injector is exposed within the processing chamber, the gas injector including at least one on-axis outlet which injects process gas in an axial direction perpendicular to a plane parallel to an exposed surface of the substrate and off-axis gas outlets which inject process gas at an acute angle relative to the plane parallel to the exposed surface of the substrate, the off-axis outlets being circumferentially spaced apart from each other, the gas injector supplying process gas at flow rates that are independently varied between the on-axis outlet and the off-axis outlets into the processing chamber;

a common gas supply in fluid communication with a first gas line and a second gas line, the first gas line being in fluid communication with the on-axis outlet but not with the off-axis outlets and the second gas line being in fluid communication with the off-axis outlets but not with the on-axis outlet; and

an RF energy source which inductively couples RF energy through the dielectric member and into the chamber to energize the process gas into a plasma state to process the substrate.

10. (Previously Presented) A plasma processing system comprising:

a plasma processing chamber;

a vacuum pump connected to the processing chamber;

a substrate support on which a substrate is processed within the processing chamber;

a dielectric member having an interior surface facing the substrate support, wherein the dielectric member forms a wall of the processing chamber;

a gas injector removably mounted in an opening in the dielectric member and extending through the dielectric member such that a single distal end of the gas injector is exposed within the processing chamber, a vacuum seal being provided between the gas injector and the dielectric member, the gas injector including a plurality of gas outlets in the single distal end which are each located below the interior surface of the dielectric member, the gas outlets including at least one on-axis outlet and a plurality of off-axis outlets, the gas outlets supplying process gas at flow rates that are independently varied between the on-axis outlets and the off-axis outlets into the processing chamber;

a common gas supply in fluid communication with a first gas line and a second gas line, the first gas line being in fluid communication with the on-axis outlet but not with the off-axis outlets and the second gas line being in fluid communication with the off-axis outlets but not with the on-axis outlet; and

an RF energy source which inductively couples RF energy through the dielectric member and into the chamber to energize the process gas into a plasma state to process the substrate.

11. (Original) The system of Claim 1, wherein the RF energy source comprises an RF antenna in the form of a planar or non-planar spiral coil and the gas injector injects the process gas toward a primary plasma generation zone in the chamber.

12. (Cancelled)

13. (Original) The system of Claim 1, wherein the ratio of gas flow through at least some of the gas outlets is independently varied using variable flow restriction devices.

14. (Original) The system of Claim 1, wherein the ratio of gas flow through at least some of the gas outlets is independently varied using a network of valves and throttling elements.

15. (Original) The system of Claim 1, wherein the gas injector is further provided with an electrically conducting shield which minimizes plasma ignition within gas passages located in the gas injector.

16-38 (Cancelled)

39. (Previously Presented) The system of Claim 1, wherein the on-axis outlet and the off-axis outlets are oriented at different angles relative to an exposed surface of the substrate.

40. (Previously Presented) The system of Claim 10, wherein the plurality of gas outlets in the single distal end of the gas injector are oriented at different angles relative to an exposed surface of the substrate.

41. (Previously Presented) A plasma processing system, comprising:

a plasma processing chamber;

a vacuum pump connected to the processing chamber;

a substrate support on which a substrate is supported within the processing chamber;

a dielectric member having an interior surface facing the substrate support, the dielectric member forming a wall of the processing chamber;

a gas injector body extending through the dielectric member such that a distal end of the gas injector body is exposed within the processing chamber, the gas injector body including a plurality of gas outlets which are disposed within the processing chamber below the interior surface of the dielectric member, the gas outlets including at least one on-axis outlet and a plurality of off-axis outlets which inject process gas at an acute angle relative to a plane parallel to an exposed surface of the substrate;

a common gas supply in fluid communication with a first gas line and a second gas line, the first gas line being in fluid communication with the at least one on-axis outlet but not with off-axis outlets and the second gas line being in fluid communication with the off-axis outlets but not with the on-axis outlet;

flow controllers providing independently adjustable flow rates of process gas between the on-axis and the off-axis outlets into the processing chamber; and

an RF energy source which inductively couples RF energy through the dielectric member and into the chamber to energize the process gas into a plasma state to process the substrate.

42. (Previously Presented) A plasma processing system comprising:

a plasma processing chamber;

a vacuum pump connected to the processing chamber;

a substrate support on which a substrate is processed within the processing chamber;

a dielectric member having an interior surface facing the substrate support, the dielectric member forming a wall of the processing chamber;

a gas injector comprising an injector body including at least first and second gas inlets, at least first and second gas passages, an axial end surface, a side surface extending from the axial end surface toward the interior surface of the dielectric member, and at least a first gas outlet in the axial end surface and a plurality of second gas outlets in the side surface at locations between the axial_end surface and the interior surface of the dielectric member, the second gas outlets inject process gas at an acute angle relative to a plane parallel to an exposed surface of the substrate, the first gas passage being in fluid communication with the first inlet and first outlet, and the second gas passage being in fluid communication with the second inlet and second outlet, the first and second gas passages not being in fluid communication with each other;

a common gas supply in fluid communication with the first gas passage and the second gas passage;

flow controllers providing independently adjustable flow rates of gas through the first and second outlets; and

an RF energy source which inductively couples RF energy through the dielectric member and into the chamber to energize the process gas into a plasma state to process the substrate.

43. (Previously Presented) The system of Claim 1, wherein the system is a plasma etching system.

44. (Previously Presented) The system of Claim 7, wherein the system is a plasma etching system.

45. (Previously Presented) The system of Claim 9, wherein the system is a plasma etching system.

46. (Previously Presented) The system of Claim 10, wherein the system is a plasma etching system.

47. (Previously Presented) The system of Claim 41, wherein the system is a plasma etching system.

48. (Previously Presented) The system of Claim 42, wherein the system is a plasma etching system.

49. (Previously Presented) The system of Claim 9, wherein the off-axis outlets are circumferentially spaced apart from each other by 120°, 90° or 45°.

50. (Previously Presented) The system of Claim 1, wherein the common gas supply comprises a single third gas line in fluid communication with the first gas line and the second gas line.

51. (Previously Presented) The system of Claim 1, wherein each of the on-axis and the off-axis outlets includes an interior orifice contoured to provide sonic or supersonic flow therethrough and the common gas supply is a gas mixture.

52. (Previously Presented) The system of Claim 7, wherein each of the on-axis and the off-axis outlets includes an interior orifice contoured to provide sonic or supersonic flow therethrough and the common gas supply is a gas mixture.

53. (Previously Presented) The system of Claim 9, wherein each of the gas outlets includes an interior orifice contoured to provide sonic or supersonic flow therethrough and the common gas supply is a gas mixture.

54. (Previously Presented) The system of Claim 41, wherein each of the gas outlets includes an interior orifice contoured to provide sonic or supersonic flow therethrough and the common gas supply is a gas mixture.

55. (Previously Presented) The system of Claim 42, wherein each of the first and second gas outlets includes an interior orifice contoured to provide sonic or supersonic flow therethrough and the common gas supply is a gas mixture.

56. (Previously Presented) The system of Claim 1, wherein at least one of the on-axis and the off-axis outlets has a uniform diameter along the entire length thereof.

57. (Previously Presented) The system of Claim 7, wherein at least one of the on-axis and the off-axis outlets has a uniform diameter along the entire length thereof.

58. (Previously Presented) The system of Claim 9, wherein the on-axis and off-axis outlets are in a planar axial end face of the gas injector.

59. (Previously Presented) The system of Claim 10, wherein at least one of the gas outlets has a uniform diameter along the entire length thereof.

60. (Previously Presented) The system of Claim 41, wherein at least one of the gas outlets has a uniform diameter along the entire length thereof.

61. (Previously Presented) The system of Claim 42, wherein at least one of the first and second gas outlets has a uniform diameter along the entire length thereof.

IX. EVIDENCE APPENDIX

1) Declaration by David J. Cooperberg Under 37 C.F.R. § 1.132 filed on September 7, 2006

Patent
Attorney's Docket No. 1015290-000546

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of	)	**MAIL STOP AMENDMENT**
David J. Cooperberg et al.	)	Group Art Unit: 1763
Application No.: 10/024,208	)	Examiner: Luz L. Alejandro Mulero
Filed: December 21, 2001	)	Confirmation No.: 9076
For: TUNABLE MULTI-ZONE GAS INJECTION SYSTEM	)	

DECLARATION BY DAVID J. COOPERBERG UNDER 37 C.F.R. § 1.132

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

1. I am an inventor of subject matter claimed in the above-identified application ("present application").

2. I received a Bachelor's degree in Applied and Engineering Physics from Cornell University in 1990, and a Ph.D. in Physics from the University of California at Berkeley in 1998. I am currently a Modeling and Sr. Process Engineer at Lam Research Corporation ("Lam") in Fremont, California. Lam is the assignee of the present application. I have worked at Lam since 1997. During this time, I have designed gas injectors and provided fluid dynamics and plasma discharge modeling support for product development. A list of my patents, published patent applications, technical publications and presentations is attached

3. I have reviewed International Publication No. WO 00/41212 to Ni et al. ("Ni"), which corresponds to U.S. Application No. 09/788,365 assigned to Lam. Based on this review, my knowledge of the design of the Ni gas injector at Lam, and my knowledge of gas injectors for semiconductor material plasma processing equipment, the Ni injector is useful for processes, such as metal etching, which can use a fixed center and edge flow pattern, but the plasma processing system claimed in the present application provides superior and unexpected results as compared to the Ni injector for multi-step etching.

4. In today's semiconductor manufacturing environment, it is necessary to vary gas compositions and flow rates during different fabrication steps in multi-step processes. Such steps can include, for example, ARC etch, photoresist etch, hardmask open, trench isolation and gate etch, which can be performed on a single substrate (wafer) in the same plasma processing chamber. During development of the present invention, it was found that the Ni injector would not meet the uniformity standards for such multi-step etch processes, wherein the gas composition and/or flow ratio is changed at least once.

5. The Ni injector shown in Figures 1 and 3A-3C includes a single bore 44 that is in fluid communication with each of the on- and off-axis gas outlets 46. A common gas is supplied to each on-axis and off-axis outlet 46 via the single bore 44. With extensive engineering design and experimentation, this Ni injector could be used to achieve a desired, fixed edge- and center-zone gas flow distribution (flow ratio) for a single-step etch process, such as aluminum etching. Consequently, the

Ni injector is impractical and cannot provide optimal process uniformity for some multi-step etch processes requiring strict uniformity standards.

6. The claimed plasma processing system includes a gas injector that provides dual-zone gas injection, i.e, center zone and edge zone gas injection, in the plasma processing chamber. The system includes an RF energy source for inductively coupling RF energy into the chamber to produce a plasma. The system includes a gas injector having at least one on-axis gas outlet and a plurality of off-axis gas outlets. The off-axis gas outlets can be adapted to inject process gas at an acute angle relative to a plane parallel to an exposed surface of a substrate supported on a substrate support within a processing chamber. The plasma processing system also includes a common gas supply in fluid communication with two different gas lines, wherein one gas line is in fluid communication with the on-axis outlet but not with the off-axis outlets, and the other gas line is in fluid communication with the off-axis outlets but not with the on-axis outlet. The system includes flow controllers that allow process gas to be supplied at flow rates that are independently varied between the on-axis and off-axis outlets, thereby allowing the gas injector to vary the flow ratio of a common gas mixture through the on-axis and off-axis outlets.

7. The claimed plasma processing system can be used to perform multi-step etch processes using a single injector design. That is, an injector designed with certain features, such as number of off-axis outlets, off-axis outlet orientation. off-axis outlet diameter and on-axis outlet diameter, can be used to perform multiple

steps of a multi-step process, in which the gas composition and/or flow ratio is changed at least once during the process, and meet uniformity standards. Consequently, the claimed gas injector is cost-effective with respect to design costs.

8. The present application includes Examples at pages 19-21 that demonstrate superior process results that can be provided by the claimed plasma processing system. As described in the Examples, the plasma processing system included an RF energy source for inductively coupling RF into the chamber to produce a plasma. The chamber included a dielectric window forming a wall of the chamber and the gas injector extended through the window. The gas injector used in the Examples included an on-axis outlet and off-axis outlets adapted to inject process gas at an acute angle relative to a plane parallel to an exposed surface of a substrate supported on a substrate support within the processing chamber. A common gas supply supplied process gas to the on- and off-axis outlets via separate gas lines. Flow controllers supplied the process gas from the common gas supply at flow rates that were independently varied between the on- and off-axis outlets into the processing chamber. The test results for Examples 1 to 3 are shown in the Table below.

Table

Example No.	Process	Predominately On-Axis Gas Flow Result	Predominately Off-Axis Gas Flow Result	Mixed Gas Flow Result
1	polysilicon etch	• etch depth of 212.9 ± 4.7 nm (± 2.2%) • range of 18.3 nm (± 1.4%)	• etch depth of 212.6 ± 5.3 nm (± 2.5%) • range of 22.3 nm (± 1.7%)	**• etch depth of 213.5 ± 2.3 nm (± 1.1%)** **• range of 7.7 nm (± 0.6%)**
2	silicon etch	• etch depth of 1299 ± 27 Å (± 2.1%) • range of 74 Å (± 1.0%)	**• etch depth of 1272 ± 14 Å (± 1.1%)** **• range of 41 Å (± 0.53%)**	• etch depth of 1295 ± 23 Å (± 1.8%) • range of 76 Å (± 1.0%)
3	polysilicon gate etch	• mean CD variation of -3.9 nm • standard deviation of 2.1 nm • range of 7.5 nm	**• mean CD variation of -3.4 nm** **• standard deviation of 1.6 nm** **• range of 5.9 nm**	

9. Specifications for etch rate and CD uniformity are continuously becoming more demanding. Requirements for etch rate can be < 2% (3 sigma) non-uniformity, i.e., more than 99.7% of the wafer surface etches at a rate which is within 2% of the mean etch rate. CD uniformity limits the etch contribution to non-uniformity to 1 to 2 nm. That is, the CDs (pre etch - post etch) measured at all locations on the wafer should be within a few nanometers of each other. The test results shown in Table 1 indicate that the best results were achieved in the polysilicon etch process of Example 1 using a mixed gas flow, while the best results were achieved in the silicon etch process of Example 2 and the polysilicon gate etch process of Example 3 using a predominately off-axis gas flow. The improvement in 3 sigma uniformity from ~2% to 1% in Example 1 is significant. Example 3 indicates that the standard deviation in CD variation (pre - post etch) is reduced from 2.1 nm to 1.6 nm for the predominately off-axis gas flow setting. These test results demonstrate that the claimed plasma processing system, which allows the gas flow ratio between the on-axis and off-axis outlets to be changed for different steps of a multi-step process, can thus provide optimized process uniformity for each such step of a multi-step process.

10. In contrast, because the Ni gas injector shown in Figures 1 and 3A-3C does not allow the gas flow ratio between the on-axis and off-axis outlets to be changed for different steps of a multi-step process, it cannot meet uniformity or customer standards for certain multi-step processes. For example, while the Ni injector can be designed to provide a mixed gas flow ratio that provides the results achieved in the process of Example 1, that same Ni gas injector would not be able to

also provide optimized process results for the processes of Examples 2 and 3, for which predominately off-axis flow conditions provided the best process uniformity. Assuming alternatively that the Ni injector can be designed to provide predominately off-axis gas flow that provides the process results achieved for the processes of Example 2 and 3, the same Ni injector would not be able to also provide optimized process results for the process of Example 1, for which predominately off-axis flow conditions provided the worst process uniformity.

11. The Examples demonstrate that the particular flow ratio of the gas flows provided from the on-axis and off-axis gas outlets, i.e., predominately off-axis flow, predominately on-axis flow, or mixed on-axis and off-axis flow, that provides the most desirable results for a given step of a multi-step etch process for a semiconductor substrate can be substantially different from the flow ratio of the gas flows that provides the most desirable plasma etch results for a different step of the multi-step etch process. For this reason, the Ni gas injector shown in Figure 1 and Figures 3A-3C is impractical for use in a plasma processing chamber for a multi-step etch process.

12. I have reviewed U.S. Patent No. 5,532,190 ("Goodyear") and note that there is a discussion in the Background section of Goodyear of the problem of lack of uniformity for plasma deposition or etching using the same gas source for a multi-zone showerhead. Goodyear solves this problem by using different gas sources for the two zones of a multi-zone showerhead. In contrast, the claimed injector can achieve uniformity using the same gas source.

13. It is my opinion that one having ordinary skill in the art would not have considered prior art showerhead electrodes in the design of an injector for an inductively-coupled (ICP) plasma processing system. Showerhead electrodes are conductive and cannot be located beneath an inductive coil of an ICP reactor. Also, showerhead electrodes are typically used in capacitively-coupled plasma processing chambers (parallel-plate reactors), which typically have different plasma density and chamber pressures than ICP reactors. Showerheads are also designed to operate in a fundamentally different manner and provide fundamentally different gas flow characteristics than the claimed injector. Showerheads typically include a large number of gas injection holes, e.g., at least 1000 holes. These holes are typically all parallel to each other, i.e., all "on-axis." In addition, showerheads are typically located close to wafers in plasma processing chambers. For example, the showerhead / wafer gap is typically about 2-2.5 cm in capacitively-coupled chambers. The gas injector / wafer gap is typically about 15 cm in an ICP plasma processing chamber for processing 300 mm wafers. Regarding gas flow, because a showerhead includes many holes, the gas exit velocity is normally sufficiently low that diffusion becomes the dominant transport mechanism. In a parallel plate reactor with a relatively narrow gap the gas distribution pattern is fairly well localized to the hole pattern, and the relative flow from each orifice. Moving a showerhead further and further from the wafer (such as to the wafer / injector distance typically used in an ICP) would make the inner and outer regions at the wafer less well correlated to the showerhead zones. This result would occur because gas leaving the showerhead would diffuse more and more in the plane parallel to the electrode before reaching the wafer as the wafer / showerhead distance is increased. In

contrast to a capacitively-coupled chamber, an ICP chamber typically has a substantially larger injector / wafer gap and gas flow is not localized simply to on-axis holes. In an ICP chamber, the supply and exhaust from the entire chamber volume also need to be considered. The higher flow rate from a smaller number of holes for the claimed gas injector allows for more controlled directivity from the injector. Thus, due to these fundamental differences, one having ordinary skill in the art would not have considered prior art showerhead electrodes in the design of an injector for an ICP system.

14. I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Date: 6/6/2006

David J. Cooperberg

David Cooperberg

Professional Portfolio

EDUCATION

University of California at Berkeley, Berkeley, CA.
Ph.D. in Physics, January 1998
Dissertation: Modeling and Simulation of High Frequency Surface Waves in Bounded Plasmas

Cornell University, Ithaca, NY.
B.S. with Distinction in Applied and Engineering Physics, May 1990

RESEARCH AND WORK EXPERIENCE

Aug. 1997 - Present — Modeling and Sr. Process Engineer
Lam Research Corporation, Fremont, CA

* Designed, implemented, and maintained a semi-empirical profile simulator for modeling feature evolution during plasma processing of integrated circuits. Used profile simulator and experimental results to develop semi-quantitative models for feature evolution in polysilicon gate, STI, photoresist trim, deep silicon trench, and contact etch process, and I-PVD of Cu.

* Provided electromagnetics, fluid dynamics, and plasma discharge modeling support for product development using commercial, university, and internally developed codes. Key contributions made in design of coils for inductively coupled plasma (ICP) reactors, dual zone gas injector, gas distribution baffles, electrode edge rings, uniformity rings, magnetic and RF shielding, and microwave applicator.

* Performed experimental study of plasma etching of patterned aluminum films which included Langmuir probe, OES, SEM, and profilometric analyses and used results along with reactor scale modeling to develop a calibrated profile evolution model with predictive capability to assist in process development.

* Developed algorithms for interferometric endpoint system. Designed and implemented code for rapid testing of endpoint algorithms based on broadband reflectance from patterned wafers.

Sep. 1992 - Aug. 1997 — Research Assistant
University of California at Berkeley, Electronics Research Laboratory

* Conducted study of surface waves in bounded cylindrical and planar plasmas via numerical simulation.
* Measured real and imaginary dispersion relations. Verified existence of surface waves having cutoff frequencies defined by ``Tonks-Dattner" resonances.
* Modeled surface wave sustained discharges in one and two dimensional bounded plasmas. Characterized these discharges by finding scaling laws, plasma impedance, wave and electron heating profiles, and electron energy distribution functions.
* Adapted and maintained electrostatic and electromagnetic Particle-in-Cell Monte-Carlo-Collision (PIC-MCC) bounded plasma simulation codes. Modifications included the design and implementation of a variable

particle weight scheme in argon and oxygen MCC packages to assist electro-negative discharge simulation and reduce computation time, the addition of electromagnetic and periodic field solving algorithms, and creation of numerous diagnostics in wk-space.

* Co-authored XGRAFIX, a graphical user interface, which runs under Unix/X Windows and provides a flexible frontend for viewing and manipulating output and controlling simulation codes.

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D. Cooperberg, V. Vahedi, "Applications of a semi-empirical, physically based, profile simulator", United States Patent 6,577,915, June 10, 2003.

J. E. Daugherty, N. Benjamin, J. Bogart, V. Vahedi, D. Cooperberg, A. Miller, Y. Yamaguchi, "Techniques for improving etch rate uniformity", United States Patent 6,344,105, February 5, 2002.

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X. RELATED PROCEEDINGS APPENDIX

None.